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An updated production model fitting for redfish (*Sebastes fasciatus* and *Sebastes mentella*) in Units 1 and 2

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Foreword

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ABSTRACT

A state-space Bayesian surplus production model (BSP) was fitted separately to Unit 1&2 *Sebastes fasciatus* and *Sebastes mentella*. This fitting used the same assumption and inputs as previous fittings in 2011 and 2012 but catch and survey data were updated until 2015. Additionally, it was possible to extend one survey data series back to 1984 which before only went back to 1990. Fits are very similar to previous fits with similar Bmsy and MSY estimates and both stocks are shown to be heavily depleted. Currently, *S. mentella* is estimated to be at about 32 kt and 14% of its limit reference point (40% Bmsy). *S. fasciatus* is estimated to be at about 43 kt and 28% of its limit reference point. BSP considers only adult/recruited biomass and therefore the present fitting cannot incorporate the abundance of the very strong cohorts of 2011 and 2012 as they have not yet recruited to adult biomass. For this reason, we have not tried to project this model. The utility of the present approach is primarily to show the level of decline experienced by these two stocks in relation to stock biomass limit reference points that are production based.

Mise à jour des ajustements au modèle de production pour le sébaste (*Sebastes fasciatus* et *Sebastes mentella*) dans les unités 1 et 2

RÉSUMÉ

Un modèle de production excédentaire bayésien état-espace (BSP) a été ajusté séparément à *Sebastes fasciatus* et *Sebastes mentella* des unités 1 et 2. Cet ajustement a utilisé les mêmes hypothèses et intrants que les ajustements précédents réalisés en 2011 et 2012, mais les données des captures et des relevés ont été mises à jour jusqu'en 2015. En outre, il a été possible d'étendre la série de données du relevé jusqu'à 1984, alors qu'auparavant, elle ne remontait que jusqu'à 1990. Les ajustements sont très semblables aux ajustements précédents avec des estimations similaires de Brms et de RMS et les deux stocks sont fortement décimés. Actuellement, le stock de *S. mentella* est estimé à environ 32 kt et à 14 % de son point de référence limite (40% Brms). Le stock de *S. fasciatus* est estimé à environ 43 kt et à 28 % de son point de référence limite. Le modèle BSP considère seulement la biomasse des recrues et des adultes. Ainsi, le présent ajustement ne peut pas intégrer l'abondance des très fortes cohortes de 2011 et 2012, car elles ne sont pas encore recrutées à la biomasse adulte. Pour cette raison, nous n'avons pas essayé de faire des projections avec ce modèle. L'utilité de l'approche actuelle est avant tout de montrer le niveau de déclin subi par ces deux stocks par rapport aux points de référence limite de biomasse du stock qui sont basés sur la production.

INTRODUCTION

In 2011, a Bayesian state-space production model (BSP) was fitted to Units 1 and 2 redfish for the purpose of assessing recovery potential after a COSEWIC recommendation (COSEWIC 2010) of endangered (McAllister and Duplisea 2011). In 2012, this approach was taken further to develop reference points for these two stocks and assess current stock state and various projection scenarios. This work showed that the Units 1 and 2 adult stock of *Sebastes mentella* was heavily depleted at only 8% of the limit reference point while the stock of *Sebastes fasciatus* was in a better state but still at just 44% of its limit reference point (DFO 2012). In 2011, there was a very large year class for *S. mentella* and also but to a lesser degree for *S. fasciatus*. It has also been found that 2012 was a large cohort for *S. mentella*. Despite the very promising future for these stocks with these year classes, adult biomass remains depleted and this will not change until about 2017 and continue for several years after.

The BSP model was refitted with updated survey indices and catches until 2015 and extended back to 1984 from the previous 1990. Because BSP does not contain indices of pre-recruits, it will be unable to predict the impact of the 2011 and 2012 cohorts but still the model has validity to show depletion of the stock from previous levels as well as provide an indication of stock potential biomass and production. In addition, BSP fits provide another view of the stock from the statistical catch at length models that are currently being applied to the stock (e.g. Duplisea et al. 2016).

DATA AND METHODS

SURVEY INDICES

Population size indices used for model fitting came from the DFO groundfish surveys in the spring, summer or fall. Swept area biomass for individuals ≥25 cm is used as the index. Previously mature biomass was used but because maturity is calculated with a logistic curve for redfish and there is a large cohort of individuals in the 16-17 cm range presently, this mature biomass would not be representative of the exploitable mature biomass which is an assumption of production models. In addition, the previous fitting contained a Unit 1 survey index starting only in 1990 but this has been extended back to 1984 which better captures some of the high biomass levels in that period and should better define the stock depletion and some of the main productivity parameters.

Unit 1: data are from DFO's summer survey in the northern Gulf of St. Lawrence from 1984 converted to Teleost-Campelen equivalent swept area biomass.

Unit 2: The Groundfish Enterprise Allocation Council (GEAC) survey which was conducted in 2000, 2001, 2003, 2005, 2007, 2009, 2011. The GEAC survey was expressed in Teleost-Campellen equivalent swept area biomass but the original gear is an Engels trawl. We note her that swept area biomass estimates of mature biomass are about 1.7X higher for this survey expressed in Engels units than in Teleost-Campelen equivalents.

CATCH DATA

Catch data extends back to 1960 and was reported for unspeciated redfish. In order to fit models to these data by species it is necessary to speciate the catch time series. This was done by determining the proportion of each species in the survey catch from each area each year and then applying a loess smoother to these proportions (Duplisea et al. 2016). The loess smoothed proportion for each year was then applied to total catch to split it into species groups. As the

survey time series does not extend as far back as the catch data, the mean proportion was applied in years before survey data were available.

METHODS

The methods used here are described in detail in McAllister and Duplisea (2011). All, starting, conditions priors and assumptions remain unchanged. The only difference in the fitting here is that catch and survey data have been updated until 2015. McAllister and Duplisea 2011 and 2012 provide sensitivity analyses of this model for these two stocks and therefore, further sensitivities are not explored here. Furthermore, because there is a large biomass of pre-recruits of both species in the system presently, we did not perform projections which would be useful in this context and therefore the present analysis is simply for estimating current stock state relative to maximums.

MODEL RESULTS

STOCK STATUS IN 2015

Sebastes mentella in Units 1 and 2

Results for the full suite of parameters estimated from the reference case run for *S. mentella* in Units 1 and 2 are summarized in Table 1. Predicted posterior median biomass levels and 95% confidence interval from the surplus production model between 1960 and 2015, as well as catch and observed stock trend indices, are shown in Figure 1.

Estimated values are quite similar to the earlier estimates in 2011. The posterior distributions for carrying capacity (K), stock biomass in 2015, and most other quantities of interest are quite precise (Table 1). The precision in estimates of variables of interest results mainly from the strong decline in the 1990s. The posterior median for B_{2015}/ B_{msy} was low at 0.057 with a posterior CV of 29% (Table 1). The strong early decline in the survey biomass series and continuance of relatively low values indicates that this stock remains depleted with a 0% probability that stock biomass in 2015 is greater than 0.4 of B_{msy}.

The stock is presently being fished at a value close to F_{msy} and at about 50% of the replacement yield (Table 1) indicating that the stock should grow. Replacement yield for this stock presently is only 2.5 kt, therefore any growth of the present adult biomass would be modest in the next year (3.6%), unless of course the 2011 year-class begins to enter adult biomass: a feature which BSP does not capture. We also note that 2015 catches have been assumed equal to those in 2014 as these catch statistics are not yet available.

Sebastes fasciatus in Units 1 and 2

Results for the full suite of parameters estimated from the reference case run for *S. fasciatus* in Units 1 and 2, are summarized in Table 2. Predicted posterior median biomass levels from the surplus production model between 1960 and 2015, as well as catch and observed stock trend indices, are shown in Figure 2.

Estimated values are quite similar to the earlier estimates in 2011. The posterior distributions for carrying capacity (K), stock biomass in 2015 is less precise than for *S. mentella* (Compare confidence intervals and CVs Tables 1 and 2) but still indicate that the stock is in a depleted state with a biomass of 43 kt which is about 20% of its limit reference point ($40\%B_{msy}$). There is almost 0 probability that the stock biomass is larger than $40\%\ B_{msy}$ (Table 2).

The stock is presently being fished at about 60% of F_{msy} and at about 34% of the replacement yield (Table 2) indicating that the stock should grow. Replacement yield for this stock presently is only 4.3 kt, therefore any growth of the present adult biomass would be modest in the next year (6.7%), unless of course the 2011 year-class begins to enter adult biomass: a mechanism which BSP does not cannot capture. We also note that 2015 catches have been assumed equal to those in 2014 as these catch statistics are not yet available.

CONCLUSIONS

The present BSP fitting is quite similar to earlier analyses (McAllister and Duplisea 2011, 2012). Both stocks are presently in a depleted state which is the same general conclusion as the previous fits. From a model stability perspective this is encouraging in that there has not been a large retrospective readjustment of stock productivity parameters and relative stock state. From a stock state perspective, it is less encouraging because it reconfirms the depleted stock state conclusion. The context of the previous BSP fitting exercise was spurred by a COSEWIC evaluation of these stocks as potentially endangered and the need to assess their recovery potential. At the time the strength of the 2011, year class was unknown and the last notable recruitment for *S. mentella* was about 30 years earlier.

The present context and utility of the model is different: BSP was fitted to adult biomass but surveys show that the 2011 and 2012 year classes of both species (*S. mentella* in particular) are very strong but BSP cannot account for this as these cohorts have not yet recruited to adult sizes. Additionally, it has been confirmed that the 2011 year class of *S. mentella* has the genetic signature of Gulf of St. Lawrence fish (Alexandra Valentin, DFO, Mont-Joli, pers com) which is the first time this has been seen for a large cohort since the early 1980s. The present BSP fitting was examined during a stock assessment framework peer review meeting held in December 2015 (DFO 2016). Because BSP considers only adult/recruited biomass, the present fitting cannot incorporate the abundance of the very strong cohorts of 2011 and 2012 as they have not yet recruited to adult biomass. For this reason, it was concluded that projections using this model would not capture adequately the anticipated increase in stock biomass.

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TABLES

Table 1. Parameter estimates and stock status indicators for S. mentella in Units 1 and 2. Posterior means, standard deviations (SDs), coefficients of variation (CVs) medians, 90% probability intervals (5^{th} and 95^{th} percentiles of posterior distribution), and are provided for all parameter estimates. K is carrying capacity, r is the maximum rate of increase, F is fishing mortality rate, MSY is maximum sustainable yield, BMSY is the stock biomass that gives MSY, Binit is the initial biomass (1960), Bcur is current stock biomass, REPY is the replacement yield in 2015. The two quantiles represent the probability that biomass in 2015 is above the critical zone [$P(B_{2015} > 0.4B_{MSY})$] and the probability that biomass in 2015 is in the healthy zone [$P(B_{2015} > 0.8B_{MSY})$]. All biomass and yield values are in kilotons.

Variable	Mean	SD	CV	5^{th} Percentile	Median	95^{th} Percentile
R	0.09	0.034	0.37	0.042	0.086	0.153
K	1126	259	0.23	779	1082	1616
MSY	24	6	0.25	14	24	34
Bmsy	563	130	0.23	390	541	808
Binit	909	203	0.22	614	887	1269
Bcur	32	9	0.27	20	32	49
Bcur/Bmsy	0.058	0.017	0.29	0.034	0.057	0.089
Bcur/Binit	0.036	0.011	0.30	0.022	0.035	0.057
Bcur/K	0.029	0.008	0.29	0.172	0.0283	0.0445
FMSY	0.0452	0.0169	0.37	0.021	0.0431	0.0766
Fcur	0.0458	0.0125	0.27	0.0284	0.0441	0.0698
Fcur/FMSY	1.1292	0.4693	0.42	0.6081	1.0256	2.0302
REPY	2.6	0.9	0.33	1.3	2.5	4.1
Catch/REPY	0.5895	0.2329	0.40	0.3287	0.5383	1.0293
q Unit 1 survey	1.35	0.28	0.21		1.32	
q Unit 2 survey	4.11	1.07	0.26		3.98	
P(Bcur> 0.4 Bmsy)	0					
P(Bcur> 0.8 Bmsy)	0					

Table 2. Parameter estimates and stock status indicators for S. fasciatus in Units 1 and 2. Posterior means, standard deviations (SDs), coefficients of variation (CVs) medians, 90% probability intervals (5^{th} and 95^{th} percentiles of posterior distribution), and are provided for all parameter estimates. K is carrying capacity, r is the maximum rate of increase, F is fishing mortality rate, MSY is maximum sustainable yield, BMSY is the stock biomass that gives MSY, Binit is the initial biomass (1960), Bcur is current stock biomass, REPY is the replacement yield in 2015. The two quantiles represent the probability that biomass in 2015 is above the critical zone [$P(B_{2015} > 0.4B_{MSY})$] and the probability that biomass in 2015 is in the healthy zone [$P(B_{2015} > 0.8B_{MSY})$]. All biomass and yield values are in kilotons.

Variable	Mean	SD	CV	5^{th} Percentile	Median	95^{th} Percentile
R	0.123	0.048	0.394	0.0554	0.1117	0.2127
K	799	246	0.308	500	738	1268
MSY	23	6	0.272	13	22	34
Bmsy	400	123	0.308	250	369	634
Binit	797	261	0.328	454	722	1214
Bcur	44	18	0.417	20	43	79
Bcur/Bmsy	0.117	0.054	0.466	0.049	0.113	0.222
Bcur/Binit	0.059	0.027	0.449	0.026	0.055	0.108
Bcur/K	0.058	0.027	0.466	0.0245	0.0566	0.1109
FMSY	0.0614	0.0242	0.394	0.0277	0.0558	0.1064
Fcur	0.0391	0.0176	0.449	0.0201	0.036	0.0716
Fcur/FMSY	0.7125	0.3673	0.516	0.319	0.6192	1.5988
REPY	4.6	2	0.428	1.8	4.3	7.7
Catch/REPY	0.3858	0.1838	0.476	0.1877	0.3391	0.8285
q Unit 1 survey	0.85	0.23	0.269		0.82	
q Unit 2 survey	3.44	1.13	0.327		3.27	
P(Bcur> 0.4 Bmsy)	0.002					
P(Bcur> 0.8 Bmsy)	0					

FIGURES

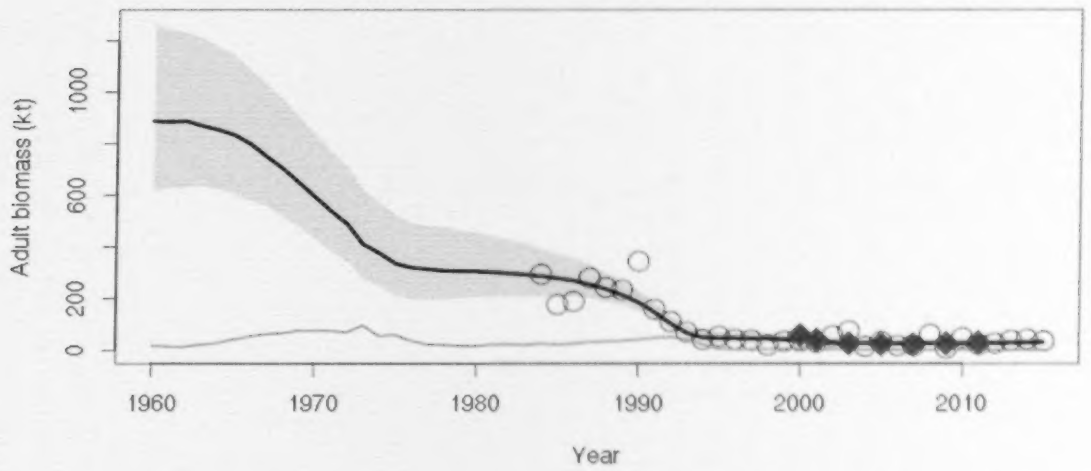

Figure 1. Plots of catch biomass (kt), and 5th,median and 95% percentiles for mature stock biomass of S. mentella in Unit 1 and 2. The survey biomass indices divided by the median estimates of q are also shown The Unit 1 survey is shown with black circles, the Unit 2 survey is show as blue diamonds. The red line is catch.

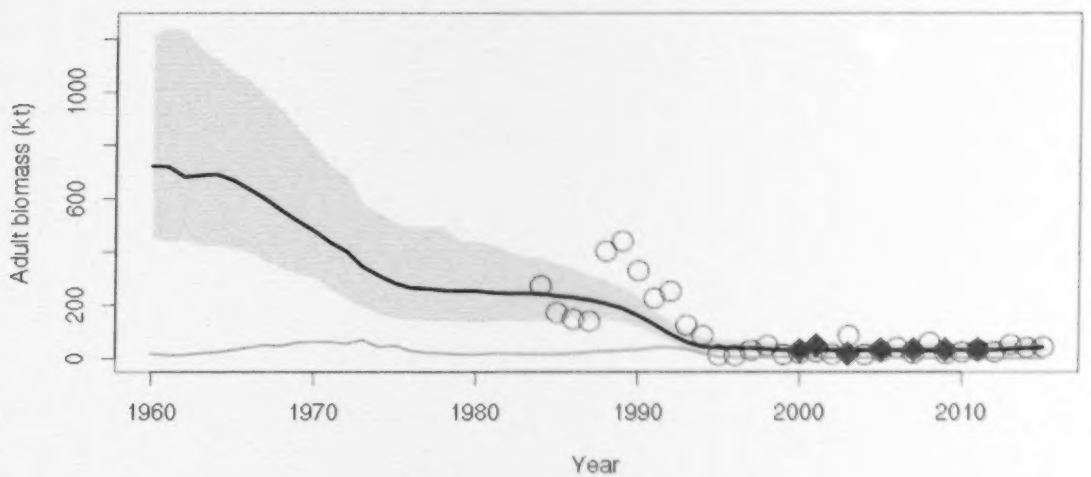

Figure 2. Plots of catch biomass (kt), and 5th,median and 95% percentiles for mature stock biomass of S. Fasciatus in Unit 1 and 2. The survey biomass indices divided by the median estimates of q are also shown The Unit 1 survey is shown with black circles, the Unit 2 survey is show as blue diamonds. The red line is catch.